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United States Patent [19]

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- [54] INFLATOR CAPABLE OF MODULATION
AIR BAG INFLATION RATE IN A VEHICLE
OCCUPANT RESTRAINT APPARATUS

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Related U.S. Application Data

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[51] Int. Cl.⁷ B60R 21/26
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[58] Field of Search 280/741, 737,
..... 280/742, 736

[56] References Cited

U.S. PATENT DOCUMENTS

- | | | | |
|-----------|---------|--------------------|---------|
| 4,341,147 | 7/1982 | Mayer | 89/7 |
| 4,523,507 | 6/1985 | Magoon | 89/7 |
| 4,523,508 | 6/1985 | Mayer et al. | 89/7 |
| 4,693,165 | 9/1987 | Magoon et al. | 89/7 |
| 4,745,841 | 5/1988 | Magoon et al. | 89/7 |
| 4,907,486 | 3/1990 | Mayer | 89/7 |
| 5,060,973 | 10/1991 | Giovannetti . | |
| 5,284,330 | 2/1994 | Carlson et al. . | |
| 5,414,845 | 5/1995 | Bredé et al. . | |
| 5,487,561 | 1/1996 | Mandzy et al. . | |
| 5,639,117 | 6/1997 | Mandzy et al. | 280/741 |
| 5,669,631 | 9/1997 | Johnson et al. . | |
| 5,683,104 | 11/1997 | Smith | 280/736 |

- | | | |
|-----------|---------|-----------------------|
| 5,695,216 | 12/1997 | Sandstrom et al. |
| 5,713,596 | 2/1998 | Messina et al. |
| 5,719,351 | 2/1998 | Johnson et al. . |
| 5,806,884 | 9/1998 | Johnson et al. |
| 5,829,784 | 11/1998 | Brown et al. |
| 5,857,699 | 1/1999 | Rink et al. |
| 5,907,120 | 5/1999 | Mooney et al. |
| 5,927,753 | 7/1999 | Faigle et al. |
| 5,941,040 | 9/1999 | McFarland et al. |
| 5,947,514 | 9/1999 | Keller et al. |
| 5,967,550 | 10/1999 | Shirk et al. |
| 5,970,880 | 10/1999 | Perotto |

OTHER PUBLICATIONS

Article entitled *faults and failures*, IEEE Spectrum Magazine, p. 17, May 1997.

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[57] ABSTRACT

In an occupant restraint apparatus for installation in a vehicle, a smart airbag inflator is provided with a piston for regeneratively pumping liquid propellant from a reservoir into a combustion chamber for ignition and combustion to generate airbag inflation gases. To control the airbag inflation rate, the piston includes a piston head slidably received in a damping chamber filled with a magneto-rheological fluid that is pumped through an orifice during the regenerative pumping stroke of the piston. An electromagnet is selectively energized to produce a varying magnetic field to adjust the viscosity of the magneto-rheological fluid flowing through the orifice and thus vary a damping force exerted on the piston stroke, thereby modulating the rate of liquid propellant combustion. Electromagnet current excitation is controlled in response to a particular accident scenario.

38 Claims, 2 Drawing Sheets

